5.4 CRITICALITY ACCIDENT ALARM & DETECTION SYSTEMS. At a nonreactor nuclear installation, criticality accident alarm systems (CASs) shall be provided to minimize, by means of quick detection and immediate evacuation alarm, the total risk incurred, and the total dose received, by personnel from a criticality accident. Exceptions to this requirement are provided in section 5.4.3. Another purpose of the CAS is to notify people to stay clear of the evacuated area and to notify appropriate response teams. In general, CASs shall be provided wherever it is deemed that they will result in a reduction in total risk. Consideration shall be given to hazards that may result from false alarms. Criticality accident detection systems (CDS), without immediate evacuation alarms, shall be provided for certain situations to permit delayed emergency response or execution of mitigating actions to terminate the criticality, protect equipment, and reduce dose to personnel.

Unless management directs otherwise, the CSO should have lead responsibility for performing CAS analyses and evaluations. However, instrumentation, controls, and alarms for criticality safety may be treated as a subset of other engineering disciplines. In any event, management should clearly designate responsibilities and authorities regarding the CAS, CDS, and interconnecting systems or devices.

5.4.1 CAS Coverage. CASs shall be installed and maintained operational for all facilities in which

- the quantities of fissionable material to be handled, processed, or stored may exceed 700 g ^{235}U, 520 g ^{233}U, 450 g ^{239}Pu, 450 g of any combination of the three isotopes, or the safe mass limits specified in ANSI/ANS-8.15-1981,R87. Individual areas may be considered unrelated when the boundaries between the areas are such that there can be no interchange of material between the areas, the minimum separation between adjacent areas is at least 10 cm, and the areal density of fissionable material averaged over each individual area is less than the fissionable equivalent mass of 50 $g^{235}U/m^2$, and

- the probability of occurrence of criticality is greater than 10^{-6}/yr, based on quantitative analysis or engineering judgment, and

- areas accessible to personnel where the maximum foreseeable absorbed dose in free air due to a criticality accident may equal or exceed 12 rad. For the purpose of this evaluation, the maximum integrated yield may be assumed to be no more than 2×10^{19} fissions.

5.4.2 CDS Coverage. CDS coverage will be provided

- when the quantities of fissionable material to be handled, processed, or stored may exceed 700 g ^{235}U, 520 g ^{233}U, 450 g ^{239}Pu, 450 g of any combination of the three isotopes, or the safe mass limits specified in ANSI/ANS-8.15-1981,R87. Individual areas may be considered unrelated when the boundaries between the areas are such that there can be no interchange of material between the areas, the minimum separation between adjacent areas is at least 10 cm, and the areal density of fissionable material averaged over each individual area is less than the fissionable equivalent mass of 50 $g^{235}U/m^2$, and

- for criticality accidents having a probability of occurrence greater than 10^{-6}/yr, based on quantitative analysis or engineering judgment, and

- for areas accessible to personnel where the maximum foreseeable absorbed dose in free air due to a criticality accident will not exceed 12 rad. For the purpose of this evaluation, the maximum integrated yield may be assumed to be no more than 2×10^{18} fissions.

5.4.3 Exceptions. CASs and CDSs are not required at nonreactor nuclear installations for the following circumstances:

5.4.3.1 Shielded Operations. Examples are spent fuel in underwater storage pools, hot cells, and buried waste.

5.4.3.2 Licensed/certificated packages. For fissionable material during shipment or material packaged in approved shipping containers awaiting transport or awaiting unpacking, provided that there is no credible criticality accident that could occur while the containers are on a loading dock or in a staging area, that there are no other operations with fissionable material not so packaged on the loading dock or staging area, and that neutron interaction between the shipping containers and other fissionable materials in adjoining areas is essentially zero.

5.4.3.3 Incredibility. Where a documented analysis concludes that no credible set of circumstances can initiate a criticality accident.

5.4.3.4 Pool storage. Underwater in spent fuel storage pools provided sufficient water shielding is maintained above the fuel to protect personnel. However, there should be a means to detect fission product gases or other volatile fission products in occupied areas immediately adjacent to the storage pool unless no fission products are likely to be released.

5.4.3.5 Burial grounds. For burial grounds where either the potential for a criticality accident is incredible, or the potential for a criticality accident is credible but the resulting dose from the maximum criticality event is less than 12 rad at the surface of the burial ground. In any event, the cause of anomalous personnel or area dosimetry results in the vicinity of burial grounds shall be investigated.

5.4.4 Design Requirements. The following provides example design and performance criteria for the CAS.

5.4.4.1 Characteristic radiation detection. The CAS shall be capable of detecting excessive amounts or intensities of radiation due to a criticality event and to signal immediate personnel evacuation. The type of radiation to be detected and the mode of detection should be uniform throughout the system.[16] However, the type of radiation detected and the mode of detection shall be consistent with the environment, radiation background, shielding, and characteristic radiation that may be observed from the postulated criticality accidents.

5.4.4.2 Alarm logic. Trip logic for the CAS units shall be based on a 1-out-of-2 or 2-out-of-N detector voting logic where $N \geq 3$. That is, either 1-out-of-2 or 2-out-of-N detectors shall trip (due to high radiation or detector/unit failure) in order to initiate an alarm.

---

[16] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 4.3.

5.4.4.3 Trouble warning. A criticality alarm unit shall not produce an evacuation signal due to component failure. Instead, a visible or audible warning signal shall be provided at some normally occupied location to indicate system malfunction or loss of primary power. Failure of any single channel shall not prevent compliance with other CAS radiation detection criteria.

5.4.4.4 Alarm purpose. The alarm signal shall be for immediate and rapid evacuation purposes only and shall be of sufficient volume to be heard in all areas to be evacuated (see section 5.4.4.16).[17] However, areas with high noise levels shall be supplemented with alarm lights as well.

5.4.4.5 Resistance to detector saturation. Detectors shall not fail to initiate an alarm because of radiation saturation when exposed to a radiation field of at least 10 rad/s[18] nor when subjected to the maximum criticality accident of concern. The CAS signal, once activated, should remain activated until reset (see section 5.4.4.6).

5.4.4.6 Alarm resets. Manual resets, with limited access, should be provided outside the areas to be evacuated.

5.4.4.7 Automated alarming. The immediate evacuation alarm shall be automatically activated by a criticality accident without the need for human action.

5.4.4.8 Response testing. The CAS units should be designed such that testing of the alarm system response and performance may be accomplished without requiring evacuation. A CAS unit shall be returned to operating condition immediately following tests or maintenance.

5.4.4.9 Minimization of false alarms and system vulnerability. CAS unit design shall incorporate features that reduce, to the extent reasonable, the frequency of false alarms and system vulnerability to external events, facility modifications, maintenance, or hazardous process conditions. All components of the system should be located to minimize damage in case of fire, explosion, corrosive atmosphere, or other extreme conditions.

5.4.4.10 Backup power supply. A backup power supply shall be provided for CAS units that is capable of supplying power to the units for a time period specified in the LCO.

5.4.4.11 Seismic resistance. In buildings designed to withstand the site-specific design basis earthquake or equivalent value specified by the Uniform Building Code, the design of new CASs should be resistant to earthquakes and should remain functional in the event of seismic shock equivalent to the site-specific design basis earthquake or the equivalent value specified by the Uniform Building Code.[19]

---

[17] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 4.4.1.

[18] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 4.5.4.

[19] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 5.5.

5.4.4.12 Response time. A CAS unit shall produce an immediate evacuation signal within 0.5 second of activation by the minimum accident of concern.[20]

5.4.4.13 Detection criteria. The CAS shall immediately detect the minimum accident of concern by activating within 0.5 second after onset. In areas affording only nominal shielding of the detectors from a nuclear criticality accident, the minimum accident of concern may be assumed to deliver the equivalent of an absorbed dose in free air of 20 rad at a distance of 2 m from the reacting material within 60 seconds. The alarm signal shall activate promptly when the dose rate at the detectors equals or exceeds a value equivalent to 20 rad/minute at 2 m from the reacting material.[21] To minimize false alarms, the trip point may be set as high as practical as long as the above criterion is met.

5.4.4.14 Sensitivity. The CAS shall be designed such that instrument response and alarm latching occur as a result of transients of 1 ms (or more) duration.[22] To minimize false alarms, the trip point should be more than 10 mrad/h above normal or operational background at the monitoring point and may be set as high as practical as long as the criteria of section 5.4.4.13 is met. Neutron detection system trip points may be set differently based on independent analysis.

5.4.4.15 Spacing. The spacing of detectors shall be consistent with the selected alarm trip point and with the detection criterion of section 5.4.4.13.[23]

5.4.4.16 Signal. A sufficient number of CAS alarm signal generators shall be installed so that the following obtain.

a. They shall produce a mid-frequency complex sound wave that may be amplitude modulated at a subsonic frequency. The fundamental frequency should not exceed 1000 Hz. Modulation should be at a rate less than 5 Hz.

b. They should produce an overall sound pressure level that is not less than 10 dB above the overall maximum typical ambient noise level, and in any case not less than 75 dB (referenced to $20\mu N/m^2$) at every location from which immediate evacuation is deemed essential.

c. They should not produce an A-weighted sound level in excess of 115 dB (referenced to $20\mu N/m^2$) at the ear of an individual.

Note: If hearing protection is required, the sound level may be measured inside hearing-protection devices, or visible alarm systems may be substituted.

---

[20] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 5.5.

[21] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 5.6.

[22] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 5.7.1.

[23] ANSI/ANS-8.3-1986, "Criticality Accident Alarm System," paragraph 5.8.

5.4.4.17 Reliability. The CAS should be designed for high reliability and should utilize components that do not require frequent servicing.

The system should be designed to minimize the effects of nonuse, deterioration, power surges, and other adverse conditions.

The design of the system should be as simple as is consistent with the single objective of reliable activation of the alarm.

5.4.5 Testing. Initial installation and subsequent tests shall be performed to provide confidence in system functionality.

5.4.5.1 Initial. Initial testing and inspections of CASs shall verify that the fabrication and installation were made in accordance with design plans and specifications.

5.4.5.2 Post repair. Following significant modification or repair to a CAS, the system shall be tested and inspected in a manner equivalent to initial installation tests and inspections.

5.4.5.3 Radiation. CAS response to radiation shall be measured periodically to confirm continuing instrument performance. The test interval may be determined on the basis of experience; however, without a documented technical basis justifying lesser frequencies, tests should be performed at least monthly, and CASs should be recalibrated at least annually. Records of tests and recalibrations shall be maintained.

5.4.5.4 Periodic. The entire CAS alarm system shall be tested periodically (at least annually). Field tests should verify (at least quarterly) that the signal is audible above background noise throughout all areas to be immediately evacuated. All personnel in affected areas shall be notified in advance of an audible test.

5.4.5.5 Corrective Action. When tests reveal inadequate CAS performance, corrective action shall be taken without unnecessary delay.

5.4.5.6 Procedures. CAS testing procedures shall be developed to minimize false alarms caused by testing and to return the system to normal operation following a test.

5.4.5.7 Records. All tests and corrective actions shall be recorded for each CAS and CAS unit. The records are to provide information on the system operability and help to identify sources of failures.

5.4.6 Location Analysis.

5.4.6.1 Shielding and location analysis. Installation management shall ensure that CAS shielding and location analyses and configuration control programs exist for all installed CASs, and that the CSO has participated in these analyses as mentioned in section 5.1.8.16.

The location and spacing of detectors should be chosen to avoid the effect of shielding by massive equipment or materials.

5.4.6.2 Yield estimation. As indicated in section 5.1.8.23, the installation CSO is responsible for estimating each facility maximum criticality accident yield to be used in safety analysis reports, alarm placements, and emergency preparedness.

5.4.7 Familiarization with Operation.

5.4.7.1 CAS alarm response. Instructions regarding the proper response to a CAS alarm signal (audible or visible) and the criticality accident evacuation routes shall be posted throughout the area covered by the CAS.

5.4.7.2 Emergency procedures. Emergency procedures shall be prepared by each FMCA and shall clearly designate CAS evacuation routes. Evacuation should follow the quickest and most direct routes practicable. Evacuation routes shall be clearly identified and should avoid recognized areas of higher risk. In addition, CAS evacuation routes shall be established such that there is no confusion with other emergency postings such as radiological hazard or toxic gas alarms or postings. The CSO should verify that evacuation routes are adequately posted.

5.4.7.3 Signal familiarization. All employees whose work may necessitate their presence in an area covered by a CAS alarm signal shall be made familiar with the sound of the signal (and location and appearance of the light, if applicable).

5.4.7.4 Signal demonstration. Before placing a new CAS in operation, all employees normally working in the area shall be acquainted with the signal by actual demonstration at their work locations.

5.4.7.5 Periodic alarm signaling. To maintain familiarization and acquaint new employees and transferees into the area, the signal should be sounded during working hours after notifying all concerned, including non-regular shift employees. This activity may be combined with the annual evacuation drills discussed in section 5.4.7.6.

5.4.7.6 Annual evacuation drills. Evacuation drills shall be conducted at least annually, and should be preceded by written notice, posted signs, or voice announcement. Surprise test evacuations shall not be conducted.

5.4.7.7 Visitor training. Untrained visitors to an area covered by a CAS should be instructed in the proper response to a CAS alarm and escorted consistent with FMCA entry requirements or as necessary to maintain control.